2.0 MANAGEMENT AND MAINTENANCE PLAN

2.1 OVERVIEW

The extent of an M&M Plan is dependent on the type, complexity, and hazard classification of the dam. Contributing factors include dam size, number and type of appurtenances, the number of operable mechanisms, and the risk imposed on downstream areas in the event of a dam failure. For example, a high hazard dam may require more frequent safety inspections, and very detailed emergency procedures. The most effective plans are usually the simplest that are easy to implement. M&M Plans will need to be reviewed and updated on a regular basis to incorporate changes or revisions to the information in the plans.

An effective M&M Plan includes three principal parts: (1) Background Data, (2) Routine Procedures, and (3) Emergency Procedures. The M&M Plan should be in writing in order to provide the owner with a logical set of instructions to follow. If well organized, this information can easily be passed on to future owners. The operation plan should provide for limited access to spillway controls, and locks on all fencing, valves, and mechanical equipment.

Table 2-1
Outline of Typical Dam M&M Plan

1. **Background Data**
   - Vital statistics
   - Important phone numbers
   - Site plan
2. **Routine Procedures**
   - Spillway, outlet & reservoir operating instructions
   - Inspection instructions, forms, and schedules
   - Monitoring instructions, forms, and schedules
   - Maintenance instructions, forms, and schedules
   - Security and safety requirements
3. **Emergency Response Procedures**
   - Identification of hazard area
   - Identification of emergency and potential risks
   - Notification procedures
   - Available resources
   - Emergency repair procedures

Background Data is a listing of pertinent dam data, or vital statistics, that describe important features of the dam and the address and telephone numbers of key personnel. A typical dam owner/operator possesses a large amount of information about his/her facility; Part 3 describes the information that should be contained in the dam owner's project files and information database. Background Data is a synopsis of the information contained in the owner's files and should be contained on one sheet of paper so that it is available for quick reference. Background Data should also include a site plan, which is a map or sketch of the dam and its appurtenant works showing all important features. Appendix A, Part 2, contains a sample Background Data Sheet that can be used in a typical dam M&M Plan.

Routine Procedures should include: operation procedures for dam features and appurtenances; inspection instructions, schedules, and checklists; instrumentation and monitoring instructions; maintenance instructions and schedules; and security and safety requirements. The instructions should identify the features that need to be inspected, monitored, and maintained, as well as any special considerations. The detailed procedures for performing inspections and maintenance should not be included in the M&M Plan. The schedules should include both day-to-day tasks, tasks performed less frequently through a given year, and preventive maintenance activities. The schedules serve to formalize inspection and maintenance procedures such that an inexperienced person could determine when a task is to be performed by consulting the M&M Plan.

The Emergency Procedures part should contain a formal plan for reacting to dam emergencies, especially if the dam has a high hazard classification. It should define coordination between the dam owner/operator, local agencies and downstream residents, as well as procedures for dealing with the emergency.

Part 2 of the Indiana Dam Safety Inspection Manual is intended to serve as a guide to assist the dam owner/operator in preparing and implementing an M&M Plan. Additional assistance from a qualified dam safety professional may also be helpful.

2.2 BACKGROUND DATA

Background Data is a list of key elements of the dam and reservoir design and operating parameters. These parameters are often referred to as the dam's vital statistics. Ideally, the vital statistics are contained on one sheet of paper which can be used as a quick reference during operation, maintenance, and emergencies. Prior to assembling the Background Data, the dam owner/operator will need to gather all the information in his/her possession regarding the dam. Examples may include design reports, photographs, plans, maps and miscellaneous correspondence pertaining to the facility. A site plan consisting of a topographic map (if available), or a dam sketch should be attached to the Background Data Sheet. Appendix A contains a sample Background Data Sheet that can be used. All of this information should be part of the dam information database contained in the owner's project files.

Maps, plans, and other sources should be reviewed for dimensions and descriptions that will provide a clear picture of the location, makeup, and function of each part of the dam. Especially important are:

1. Overall dimensions of the dam

Table 2-2
Suggested Contents of Background Data Sheet

1. General Information
- owner address & phone no.
- county location
- township location
- stream name
- year completed
- hazard classification
- important telephone numbers
- significant problems in the past

2. Dam and Embankment
- type of dam
- height of dam
- length of crest
- width of crest
- angle of upstream slope
- angle of downstream slope
- available freeboard
- top of dam elevation

3. Spillway
- type and dimensions of spillway
- dimensions of spillway crest
- spillway crest elevation
- normal pool elevation
- available freeboard
- greatest depth & date of occurrence
- design capacity
- discharge channel

4. Outlet (if present)
- size and type of outlet
- size and type of outlet control device
- inlet invert elevation
- outlet invert elevation

5. Monitoring Devices (if present)

6. Hydrology and Hydraulic Data
- maximum capacity of dam
- design storm event
- design storm flow
- reservoir stage-storage tables
- reservoir stage-discharge tables
- time of concentration
- watershed area

2. Spillway configuration and operation
3. Outlet configuration and operation
4. Drainage systems and outfall locations
5. Location and detail of monitoring points
6. Capacity tables for the reservoir
7. Discharge tables for the outlet and spillway
8. Location and capacity of inflow and outflow ditches
9. Records of past inspections, monitoring, repairs, and operating problems
10. Photographs of pertinent features or problems on the dam, taken annually and kept on file for comparison and reference.

If a detailed set of drawings for the dam does not exist, a plan or sketch, and representative cross sections should be drawn up. If a dam was constructed with a detailed topographic map with grading plans, this may be used to depict the key features. However, many dams were constructed without plans, or have no plans at all. If the dam is relatively large, has maintenance and repair concerns, or is a high hazard dam, a survey of existing conditions and features may need to be performed and a topographic map prepared.

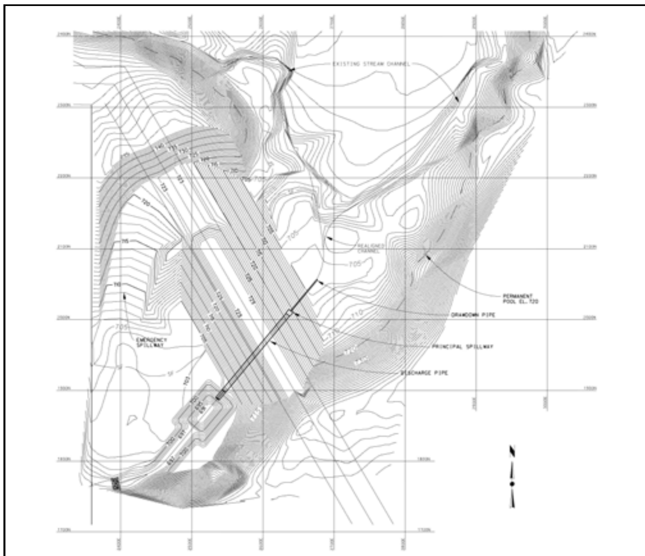

Figure 2-1 Grading plans for a small embankment dam.

2.3 ROUTINE PROCEDURES

Routine Procedures should include the instructions, forms, and checklists that will be used to operate and maintain the dam. These materials should be prepared to guide the day-to-day operations so that nothing is overlooked and that inspections and maintenance are performed when required. This part of the M&M Plan includes the following information:

- operating instructions for spillway, outlet, and reservoir
- inspection instructions, forms, and schedules
- monitoring instructions, forms, and schedules
- maintenance instructions, forms, and schedules
- security and safety requirements

Routine Procedures do not include detailed inspection and maintenance procedures since these procedures are voluminous. Rather, they contain a guide and schedule for performing these activities. The detailed procedures for inspection and maintenance should be contained in the owner's project files. The Indiana Dam Safety Inspection

Manual contains typical details for inspections and maintenance and may be used as the basis for these procedures. Detailed procedures for reservoir operation and monitoring may be included in the M&M Plan since these procedures are generally brief and concise.

2.3.1 Operating Instructions

The M&M Plan should provide complete, clear, step-by step instructions for operating all mechanisms associated with the dam. This will typically include the outlet conduit control valve, flashboards, or possibly the spillway gates if applicable. Proper sequences should be emphasized and sketches, drawings, and photographs to aid in identifying specific handles, cranks, buttons, etc should be included. The correct method of opening and closing guard gates, gate usage during low and high flow, openings at which excessive vibrations are experienced, operating problems peculiar to a specific gate, and maximum reservoir drawdown rate should also be listed. For hydraulic and electric gates, a schematic diagram should be provided showing each component (including back-up equipment) and its place in the operating sequence.

Instructions on the general operation of the reservoir, including the regulation of inflow and outlet devices, should be given. These should state the maximum pool levels to be allowed at different times of the year, maximum and/or minimum carry over storage, and maximum and/or minimum permissible outlet releases. They should also describe operation of the outlet to limit or prevent excessive spillway flow, and the method for periodic drainage of the reservoir to permit thorough outlet or upstream slope inspection.

If periodic or ongoing releases are required for downstream water flows, irrigation, power generation, or other purposes, instructions and schedules should be included for maintaining the proper release rate. Release rates and dates should be recorded and placed in the owner's project files.

The operating instructions should also include specific security and safety measures that are deployed at the site. This includes such things as location of fences, locks, and key-holders. It should list specific areas at the dam and around the reservoir that present a potential safety concern for site visitors and maintenance personnel, and areas where "no-trespassing" signs or "warning" signs are to be posted. Most dams and reservoirs have areas that are dangerous to visitors, such as steep slopes, areas that are slippery when wet, or areas where poisonous snakes may be present. A map or sketch showing the location of these elements may be included in the M&M Plan.

It should be noted that the typical dam in Indiana is an earth embankment dam that does not include extensive mechanical or electrical equipment. The most complicated mechanical equipment at most dams is typically an outlet drain with a control valve. This situation requires minimal operating instructions. However, safety and security provisions should be addressed at all dams, and signs should be posted at a minimum in areas where dangerous conditions may be present.

2.3.2 Inspection Instructions

Table 2-3
Inspection Recommendations

(1) **Formal Technical Inspection:** Performed initially for all dams and on a regular basis (2 to 5 yrs) thereafter.

(2) **Maintenance Inspections:** Performed on a regular basis (annual) for all dams; formal technical inspections may be conducted in place of maintenance inspections.

(3) **Informal Inspections:** Performed on an impromptu, non-scheduled basis whenever the opportunity arises, or as part of a dam monitoring program.

(4) **Special Inspections:** Performed after the occurrence of unusual or extreme events, or emergencies.

A clear, step-by-step set of instructions for conducting dam safety inspections of the dam and its surroundings should also be provided. Inspection checklists (and IDNR Report Forms for high hazard dams) for recording data should be used and copies of all completed inspection records should be kept in the owner's project files. The instructions should include a list of the features to be inspected, inspection frequency and schedules, and inspection team members. The inspection team may consist of the dam owner or dam operating personnel, or it may consist of engineering consultants, depending on the type of inspection and current IDNR regulations.

The instructions should specify the type of inspection that will be performed for the given schedules and frequency. Generally, four types of inspections will be performed: (1) formal technical inspections, (2) maintenance inspections, (3) informal inspections, and (4) special inspections.

Reporting procedures should also be spelled out, including the type and format of the report, and where the report will be placed. The report may need to be submitted to IDNR by a specific date if the dam has a high hazard classification, depending on current IDNR regulations.

Part 3 of the Indiana Dam Safety Inspection Manual provides details of inspection procedures that can be used to perform the dam inspections. It also contains a copy of a sample inspection checklist and the IDNR Report Form.

2.3.3 Monitoring Instructions

The M&M Plan should include clear instructions on how to use monitoring instruments, and when and how to take measurements at monitoring points. The purpose of each monitoring point or instrument should be stated in the instructions. A map identifying each instrument and monitoring point should also be included. Field forms for recording the data should be provided in the instructions. The monitoring points themselves, plus any seepage or other areas needing special attention should be kept clear of obscuring growth and be permanently marked, so they can be found during inspection. The monitoring points should be shown on the dam site plan discussed earlier. The help of a qualified engineer or other dam safety professional may be useful in developing this section. Subchapter 3-10, Part 2, contains more information on instrumentation and monitoring.

Monitoring can only be beneficial if the observations are recorded in an orderly way and form a clear performance record. Thus, plotting or charting of the readings will be necessary. Instructions on how to make and record each measurement or observation must be provided. If the owner's engineer is not going to plot or chart the data, instructions and forms should be developed to allow owners, operators, or maintenance personnel to do this work. An engineer or other experienced dam safety professional should be consulted for help in preparing the needed forms and with reviewing/evaluating the data and plots.

Chapter 3 (Part 2) includes typical guidelines and information for monitoring a dam.

2.3.4 Maintenance Instructions

The M&M Plan should include detailed instructions and schedules for performing periodic maintenance work at the site. This should include maintenance of the dam, the appurtenant works, and the reservoir areas. This will allow new personnel to understand the tasks and experienced personnel to make sure that they have completed the work properly.

All needed maintenance work should be identified and listed. Dam maintenance includes both routine preventive maintenance and repair of problems identified during safety inspections. Preventive maintenance includes work that is performed to maintain the dam and reservoir in good working condition and to prevent more harmful conditions from developing. This includes such tasks as mowing grass, repair of erosion rills, and removal of burrowing animals from the site. Individual maintenance tasks should be itemized on the list, with a description of the area where the maintenance is to be performed, the time it takes to complete each task, the equipment that is required, who will perform the work, the schedule for performing the tasks, and reporting procedures. Maintenance that involves the repair of problems identified during inspections should also be planned out, listing the same details as needed for preventive maintenance. Dam repairs should be scheduled based on severity of the problem, available resources, and weather conditions. For example, if a severe settlement problem is identified on the crest of the dam, it should have a high priority since further degradation could lead to

Figure 2-2 Dam needing vegetation maintenance.

dam breaching. The cause of major maintenance items, such as excessive settlement, should be identified by a qualified dam safety professional. Correcting minor rill erosion on the downstream slope could be assigned a low priority since it is not a dam safety concern. This type of repair will also be weather dependent, since grass can only be planted during specific times of the year, and the embankment should be relatively dry so that additional damage is not inflicted to the embankment slopes.

Typical routine maintenance tasks performed at most dams include the following:

- Mowing grass
- Removing brush and trees
- Removing litter and other debris
- Regrading the crest and/or access roads
- Removing burrowing animals
- Operating and lubricating gates
- Adding riprap when needed
- Sealing joints in concrete facings
- Cleaning spillway and outlet conduits
- Maintaining monitoring points
- Maintaining security of operating equipment
- Reseeding and fertilizing grass
- Testing of emergency power sources

Other maintenance that may need to be performed varies from dam to dam and is usually the result of weathering and the destructive forces encountered in the dam environment. This includes such things as repair of: embankment sloughs and slides, seepage problems, severe erosion, displaced riprap, shoreline wave erosion, embankment settlement, and concrete cracking and disintegration.

The dam owner should prepare work forms for routine items and non-routine items as well. The forms can be used to ensure the maintenance is properly completed, to track the maintenance and repairs, and to keep an up-to-date project file. The key to a successful routine maintenance program is the establishment of a schedule for performing the tasks, and compliance with that schedule.

Chapter 4 (Part 2) includes typical guidelines and information for maintaining a dam.

2.4 EMERGENCY RESPONSE PROCEDURES

Every dam owner should develop emergency response procedures as part of the M&M Plan. Emergency response procedures should consist of a clear, concise set of instructions for dealing with emergencies or potential failures at the dam.

Emergencies that threaten the safety and integrity of a dam could arise at any dam. Emergencies usually develop as a result of severe weather conditions, storms, or seismic events. However, poor dam design, construction, or maintenance may contribute to or result in an emergency. For example, a riser spillway could become clogged as a result of an improper or no trash rack, causing the reservoir level to rise and threaten the embankment stability. Or, unnoticed or uncorrected seepage problems could progress and create a potential slope stability or seepage emergency.

The amount of time that a dam owner has to react depends on the cause and severity of the emergency. If a large rainstorm is occurring and the reservoir level is rapidly rising, there may be little time to respond to the situation, and immediate action may be required. However, if a problem is relatively minor and does not pose an immediate risk to the dam stability or safety, there may be time to plan and schedule the necessary repairs (these problems are not actually emergencies, but do require attention).

In general, responses to dam problems and emergencies can be divided into three categories:

(1) **Low priority response**; implement a low priority notification procedure, and schedule and perform maintenance repairs in the near future. “Near future” depends on available resources, and the severity of the deficiency.

(2) **Medium priority response**; implement a medium priority notification procedure, and perform emergency repairs as soon as possible. “As soon as possible” is subjective, and the timing depends on the urgency of the situation.

(3) **High priority response**; implement a high priority notification procedure, and perform emergency repairs immediately. “Immediately” means now.

Table 2-5 can be used to help classify the response level required for significant dam problems and emergencies. Subchapter 2.4.3 describes procedures for the various levels of notification.

The emergency response procedures included in the M&M Plan should include the following information and procedures:

- identification of hazard area
- identification of emergency and potential risks
- notification procedures
- available resources

Table 2-4
Suggested Emergency Response Procedures

- Identify the emergency and potential risks
- Determine the response level and urgency
- Estimate the amount of time before failure may occur, if applicable
- Implement notification procedures
  - Low level notification for low priority problems
  - Medium level notification for emergency conditions
  - High level notification if failure may occur
- Mobilize equipment and resources to perform repairs
- Implement emergency repair procedures

High priority notification:
- Notify emergency coordinator, local police, fire department, and state police
- Warn residents living immediately downstream from the dam
- Notify the Indiana Department of Natural Resources
- Contact a qualified engineer for assistance
- Notify other agencies/person as deemed necessary
- Contact a repair contractor and material supply sources

Medium priority notification:
- Notify dam owner and/or emergency coordinator
- Contact IDNR and a qualified engineer for assistance
- Contact a repair contractor and material supply sources

Low priority notification:
- Notify dam owner and maintenance personnel

- emergency repair procedures

Table 2-5 Guide for Classifying Dam Response Level

Condition or Problem	**Low Priority Response** (New or Increased Problem)	**Medium Priority Response** (Possible Failure Developing)	**High Priority Response** (Failure of Dam in Progress)
Response Urgency	Normal	Emergency	Extreme Emergency
Response Time	Near future	As soon as possible	Immediately
Notification Procedure	Low priority	Medium priority	High priority
Repair Urgency	Maintenance repairs	Emergency repairs	Emergency repairs (urgent)
Failure Status	No failure imminent	Type 1 failure (dam component failure)	Type 2 failure (uncontrolled dam breach)
Embankment Overtopping	Reservoir is rising due to blocked spillway – no storm event occurring	Reservoir is rising and is getting close to or is at emergency spillway level – no storm event is occurring	Reservoir is at or is overtopping dam causing erosion
Slides	Small, or surface slide with minor reduction of dam cross section; minor settlement; not moving or changing	Moderate slide which reduces dam cross section; no seepage or overtopping is occurring	Large slide which reduces dam cross section significantly; seepage or overtopping is occurring
Settlement	Minor settlement (<1 ft) and not progressing	Active settlement	Significant settlement; overtopping is occurring or is imminent
Cracking	Small, dry, shallow cracks in non-critical areas	Active cracks with displacement or minor seepage (clear water), or in critical areas	Significant cracking with muddy water
Backcutting of Emergency Spillway	Some erosion of spillway is progressing slowly	Erosion of spillway is progressing rapidly	Spillway has washed out, dam breaching occurred or imminent
Sinkholes	Small depressions in dam or foundation; not over critical component; not changing	Large hole over outlet, or on dam or foundation; not increasing or progressing slowly	Unstable hole over outlet, or on dam or foundation; whirlpool in reservoir
Seepage/Piping	Downstream slope is wet and soft; minor sloughing; no flowing water; no sediment in seepage or drains	Seepage is causing slides which narrows dam cross section; settlement of crest and loss of freeboard; flowing water and potential for piping	Seepage has caused large slide which has reduced freeboard to reservoir level, or dam is overtopping; piping has occurred: Sink holes in dam; whirlpool in reservoir; settlement; significant muddy water
Wave Erosion	Minor erosion, and/or minor scarping of upstream slope	Moderate and/or significant scarping of the upstream slope which is progressing towards crest	Significant erosion of crest height and/or rapidly progressing loss of upstream slope
Conduit Spillway	Minor deterioration of conduit; displaced riprap at outlet; soil adjacent to conduit outlet is wet, but no flowing water	Conduit is moderately deteriorated; flowing water adjacent to conduit and potential for piping; some settlement over conduit	Conduit is severely deteriorated; joints are leaking; piping is occurring along conduit; significant sinkholes or settlement above conduit.
Outlet Failure	Deteriorated gate or controls; rusty, scaling pipe; seepage	Cracked or perforated pipe; sediment in seepage; deeply scoured or undermined conduit; broken gate controls	Significant, muddy seepage from or adjacent to outlet; sinkholes in embankment over outlet conduit

Dam owners, operating personnel, and/or their engineers must be prepared to act promptly and effectively when a dam begins to show signs of uncontrolled breach failure. Early identification of a potential breach situation may provide additional time to warn and evacuate downstream residents and to implement measures to prevent or delay dam failure.

Because failure of a dam may take only minutes or hours to occur, it is imperative to have a detailed plan of action ready for use. However, the dam owner should use caution and must be able to make sound decisions regarding the severity of the emergency. The dam owner must assess whether the emergency condition will result in a dam component failure (Type 1) or an uncontrolled breach failure (Type 2), or whether no failure will result at all. Unnecessary evacuation of the downstream areas can be costly and detrimental to the dam owner's public image, especially if the hazard area is large and involves a large number of people and properties.

A detailed Emergency Action Plan may be prepared in lieu of emergency response procedures. The Emergency Action Plan is significantly more detailed; it is described in Part 1 of the Indiana Dam Safety Inspection Manual.

2.4.1 Identification of Hazard Area

The hazard area is the area(s) that will be affected by a dam emergency. Typically, it is the downstream area that would be affected in the event of a dam failure. However, the hazard area may also include upstream areas that may be flooded as a result of rising reservoir levels.

Figure 2-3 A large storm event can provide insight to areas of inundation in the event of a uncontrolled dam breach failure.

The dam owner should be aware of the properties and structures that could be affected if a dam failure occurs. The dam owner may be legally and financially liable for all damage that is incurred. Hazard areas may be identified using USGS Quadrangle maps, FEMA Flood Insurance Rate Maps, aerial photography and mapping, or by visual inspection of the areas adjacent the dam and reservoir. Detailed engineering studies involving dam breach analyses may also be performed to determine the hazard areas. Maps showing potential areas of flooding as a result of a dam failure are especially useful. More detailed information concerning the identification of inundation areas and the development of mapping of potential flood areas is available from the IDNR.

The estimated hazard area should be shown on a map, such as a current USGS quadrangle map. The map should be made part of the M&M Plan and kept on site in the owner's project files. Roads, buildings, dwellings, and other dams that could be affected by a dam failure should be identified on the map.

Typically, very few inundation maps are available for local officials to use in their emergency warning and evacuation plans. Consequently, local officials and dam owners will have to use available mapping and common sense in determining the potential hazard areas.

If the dam is a high hazard dam and has a large reservoir pool, evacuation of the downstream hazard area may be required if emergency repair measures are unsuccessful and dam failure is imminent. Areas nearest to the dam should be evacuated first. Flood Hazard Boundary maps can provide rough approximations of necessary evacuation areas. However, the evacuation area should be extended beyond the limits of the maximum flood area shown on these maps as floods resulting from dam failures are usually more widespread and destructive. When making these determinations, it is always better to err on the conservative side.

Whenever possible, warning of a dam failure or an impending dam failure should follow procedures already established for other emergencies in the area where the dam is located. However, it must be stressed that warning and evacuation times will be limited and that immediate evacuation must follow. Warnings delivered through personal modes such as telephones, loudspeakers, and face-to-face communications are more effective than warnings delivered impersonally, by sirens for example. Persons delivering the warnings should always say "the dam is failing," and not "flooding is expected." Warnings should be clear and concise. Residents should be advised to move to safety immediately. Police, radio and television news media should be used to the extent available and appropriate. Residents are more likely to respond if they receive warnings from several sources.

Evacuation routes and roadways should be identified. Roadblocks along potentially flooded routes may be required, and should also be identified ahead of time. Agencies and/or persons that will be required to perform emergency tasks should be identified.

The farther downstream a damage center is located, the more chance there is for a long flood warning and more time to carry out an organized evacuation. Protection of life should also be considered before anything else in an evacuation effort.

It should be noted that most dams in Indiana are not high hazard and may not require any downstream notification or evacuation.

2.4.2 Identification of Emergency and Potential Risks

Early identification of emergencies and unsafe conditions at a dam will allow prompt implementation of emergency actions and procedures. Dam owners and operators should be familiar with the principal types of failure and their telltale signs, especially if they may result in an uncontrolled breach failure. If any of the following conditions are noted, the high level emergency procedures should be implemented immediately.

1. The dam is overtopping or nearly overtopping. The dam owner or operator should closely monitor the level of the reservoir during periods of heavy rainfall and runoff. If the spillway and reservoir storage capacities are exceeded, overtopping may occur. Overtopping could result if a large slide on the upstream or downstream slopes of the embankment has significantly lowered the dam crest. Blockage of pipe spillways and risers may also cause overtopping of a dam. Other conditions which could cause overtopping include significant settlement on the dam crest, sinkholes, excessive embankment soil erosion, spillway and embankment cracks, and wind-blown trees.

Figure 2-4 Water is starting to overtop this embankment.

2. Piping (internal erosion of soil from the dam or its foundation) has developed. Piping is usually indicated by a rapid increase in seepage rate, a muddy discharge at or near the downstream toe, sinkholes on or near the embankment, and/or a whirlpool (eddy) in the reservoir. Boils at or near the downstream toe may be indications that piping is beginning. Piping may also develop along spillway and outlet conduits.

3. A large slide develops in either the upstream or downstream slope of the embankment and threatens to release the impounded water by lowering the dam crest.

4. Sudden and rapid failure of an appurtenant structure threatens complete failure of the dam and release of its impoundment.

Identification of any of these conditions at a dam should be cause for alarm and the emergency procedures should be implemented promptly. If there is any question as to the severity or urgency of the suspected problem, a qualified dam safety professional should be contacted. IDNR may also be contacted for additional advice.

The dam owner should prepare a list of critical dam features and conditions that would be checked during any emergency. For periods of unusual activity (heavy rains, earthquakes, embankment instability, etc.), the owner should record reservoir levels to determine the rate of pool rise or fall. Inspection of the embankment, downstream toe and abutments for wet areas or seepage for indications of piping through the structure or foundation is important during these events. The owner should check for abnormal sloughing of earth, depressions, and horizontal and vertical displacement of the embankment and concrete structures. If the dam is instrumented, monitoring should be performed to detect changes from normal readings that would indicate distress in the embankment. If overtopping occurs, the embankment should be closely monitored for signs of deterioration. Table 2-5 can be used to help classify dam emergencies and response levels.

After the emergency condition is identified, the potential risks associated with the condition should be evaluated. The severity of the risks will be dependent on the type of condition, reservoir level, size of reservoir, proximity of downstream property and structures, potential success of emergency repairs, etc. The risks may include release of small quantities of water from the reservoir, release of larger quantities of water, or complete dam breaching and failure. Depending on the severity of the risk to the dam, associated risks to the hazard area(s) should also be assessed. These risks may include shallow flooding of properties, extensive flooding of properties, total destruction of dwellings and other buildings, flooding of public roads, breaching of downstream dams, severe erosion, etc. The owner should determine whether the emergency will result in an uncontrolled breach failure and subsequent release of a significant quantity of water before proceeding with notification procedures.

The level of notification will depend on the severity of the emergency condition, so it is very important that the safety concerns and risks are accurately identified. Unnecessary notification should be avoided.

2.4.3 Notification Procedures

As flows over the spillway continue to increase, the owner must make a determination as to whether the embankment might be overtopped. When a determination has been made that lives and properties downstream from the dam are in serious jeopardy, notification of the appropriate agencies/persons (presented below) should be accomplished using available and predetermined communications. The dam owner should designate an “emergency coordinator(s)” that will be responsible for the coordinating all emergency activities and implementing the notification procedures. Two different notification procedures should be developed based on the type of the emergency and the hazard classification of the dam. If the emergency condition will or may result in an uncontrolled breach failure of the dam, and downstream people and structures will be affected, a **high priority notification** process should be implemented. If the emergency condition will not result in an uncontrolled breach failure of the dam, or no people or structures will be affected downstream, a **medium priority notification** process should be implemented. A third notification level, low level, is implemented for non-emergency situations where sufficient time is available to perform repairs, and the dam safety and integrity is not at immediate risk.

The response to a critical emergency situation that will or may result in an uncontrolled breach failure that will affect downstream people and structures should proceed in four steps (high priority notification). First, the owner or person who identifies the emergency should notify the emergency coordinator and/or dam owner, local law enforcement officials, and those persons residing immediately downstream from the dam. Law enforcement and local officials should then proceed with warning and evacuation procedures for potentially affected areas. Second, after notifying local law enforcement officials, the owner should contact a qualified engineer and other agencies/person (if necessary) to assist with the emergency. Third, the owner should initiate efforts to prevent or delay the failure, including contacting repair contractors and material suppliers as may be needed. Fourth, the owner or operator should notify IDNR Dam Safety personnel of the incident within 24 hours. The sequence of actions for a high priority notification is summarized below.

Owner/ Observer:

1. Notify emergency coordinator and/or owner, local officials, and warn residents living immediately downstream from the dam. Local officials include local police, fire department, and state police.
2. Contact a qualified engineer and other agencies/person as deemed necessary for additional assistance (see list below).
3. Implement actions to prevent or delay failure, including contacting repair contactor(s) and material suppliers.
4. Notify the Indiana Department of Natural Resources, Division of Water, Dams and Levees Section within 24 hours of the incident.

Local Officials:

1. Determine affected area.
2. Implement warning/evacuation plan.

If the emergency does not pose an uncontrolled breach failure or will not affect downstream people and structures, a medium priority notification process should be implemented. This process consists of the following three steps:

1. Notify dam owner and/or emergency coordinator
2. Contact a qualified engineer for assistance
3. Implement actions to prevent or delay failure, including contacting repair contactor(s) and material suppliers.
4. Notify the Indiana Department of Natural Resources, Division of Water, Dams and Levees Section within 24 hours of the incident.

The dam owner should establish a list of agencies/persons to be contacted as part of the notification process. Input for this list should be obtained from and coordinated with local law enforcement officials and county disaster assistance personnel. The following agencies/persons can offer emergency assistance in the event failure of the dam appears imminent:

1. Owner/operator (home and office)
2. Employees actively involved with dam
3. Local sheriff, police, and/or fire departments

4. State Police
5. County Disaster Services Agency
6. County Engineer
7. Indiana Department of Natural Resources, Division of Water, Dams and Levees Section
8. Local emergency management (civil defense) agencies (county and municipal)
9. Emergency Medical Services
10. Downstream residents (if practical).
11. Qualified local engineering consultants
12. Local repair contractors and material suppliers

A copy of the notification list should be posted in a prominent, readily accessible location at the dam, near a telephone and/or radio transmitter, if possible. This list should be periodically (once or twice a year) verified and updated as necessary. The list should include individual names and titles, locations, office and home telephone numbers, and radio frequencies and call signals as appropriate. Special procedures should be developed for nighttime, holiday, and weekend notification and for notification during a severe storm when telephones may not be working or highways may be impassable. The notification plan should be brief, simple, and easy to implement under any set of emergency conditions.

A primary and backup communication system which considers the possibility of a potential power blackout should be identified in the plan. Cell phones may be used in a situation like this.

A predetermined time should be established when evacuation efforts are to be terminated. Previous studies may be available to indicate at what flood level it is no longer safe to continue evacuation in each area. The time it takes for peak flood levels to reach the dam and the time needed to evacuate all people and equipment should be the determining factors in terminating evacuation assistance.

The following information should be reported when an emergency notification procedure is implemented:

1. Name of dam, lake, or reservoir, and river, stream, or tributary the dam is located on.
2. Location from highway or nearest town (U.S., state, or county road numbers); also section, township, and range, if known.
3. Nature of the problem (e.g., excessive leakage, cracks, sand boils, slides, wet spots, etc.).
4. Location of problem area in terms of embankment height, (e.g., about 1/3 up from the toe) and location along the dam's crest (e.g., 100 feet to the right of the outlet or abutment) and whether on the upstream slope, crest, or downstream slope.
5. Extent of the problem area and the amount of time until failure occurs.

6. Estimated quantity of unusual flows as well as whether the water is clear, cloudy, or muddy.
7. Water level in the reservoir below the dam's crest or below the spillway, or the gage rod reading.
8. Whether the water level in the reservoir is rising or falling.
9. Name and how to contact the person making the report.
10. Whether or not the situation appears to be worsening.
11. Whether or not the problem appears to be containable at the time of the report, or whether it is an emergency situation.
12. Current weather conditions at the site.
13. Anything else that seems important.


Figure 2-5 Backhoe being used to place an emergency pump in the reservoir.

This list should be periodically reviewed by owners' representatives who frequently visit the dam site. It will alert them to make all these observations before reporting the incident. An accurate report will allow an accurate assessment of the situation and proper implementation of the emergency response procedures.

Figure 2-6a Riser without a trash rack was clogged with the wood pallet in foreground.

A low level notification process is used when normal, low risk dam problems are found. This process consists of notifying the dam owner and maintenance personnel of the observed condition. Even though an emergency may not be present, low level problems should be identified early and scheduled for repair in the near future to prevent them from becoming worse.

2.4.4 Available Resources


Figure 2-6b The riser in figure 2-6a is visible after pallet is removed and water is drawn down.

The emergency response procedures should include a list of available resources that may be needed during a dam emergency condition. The dam owner should immediately initiate efforts to prevent or delay failure of the dam. Because of the likely limitation on time, it is important to identify in the emergency response procedures the location of available resources which may be used to attempt to avoid (delay or prevent) the failure. Any emergency repairs will require equipment, materials, labor, and expertise. For large reservoirs where failure could result in loss of life or severe damage to high value property, materials (clay, sand, gravel, stone, riprap, sandbags, cement, plastic sheeting, etc.) and equipment for handling these materials should be kept at or near the site. If this provision is not possible, then prior arrangements for use of locally available, off-site materials and equipment should be made in case of an emergency. Equipment that may be needed includes pumps, dozers, backhoes, front-end loaders, trucks, and boats. A list of local contractors and other labor sources should be prepared and kept up-to-date. Telephone numbers where these people can be contacted 24 hours per day should be included. The dam owner should contact the potential contractors ahead of time and obtain their cooperation in advance.

2.4.5 Emergency Repair Procedures

The emergency response procedures should also include potential repair procedures that may be implemented for the different types of emergencies that could threaten the dam. The most likely modes of failure were described earlier. It is important to know what types of emergency repairs should be attempted for the different modes of failure.

Owners should not allow temporary actions to become permanent repairs. This practice is dangerous because the chance of a rapid and catastrophic failure may increase if the repairs are not adequate. A qualified dam safety professional should be contacted to recommend appropriate permanent remedial measures.

Repair procedures will be dependent on the type of safety concern or emergency condition that is encountered. An emergency condition is considered to exist if either a Type 1 (component failure) or Type 2 (uncontrolled breach failure) failure has occurred or is imminent. A Type 1 failure requires a medium priority response, while a Type 2 failure requires a high priority response. Emergency repairs should be performed when either type of failure situation exists. Maintenance repairs should be performed when dam deficiencies are minor and have not progressed to an emergency status. Table 2-4 can be used to help determine if an emergency exists and the level of urgency for performing repairs.

The remainder of this chapter presents guidelines for performing emergency repairs for Type 1 (medium priority) and Type 2 (high priority) failure modes.

High priority emergency repairs (emergencies that could result in uncontrolled breach failure (Type 2).

These emergencies usually require immediate action to prevent the release of the reservoir. Therefore, it is very important that the dam owner or operator be prepared ahead of time so that a rapid response is possible. The following descriptions of possible actions to take during emergencies that could result in an uncontrolled breach are offered as guidance. These measures are preliminary and may need further development in the site specific emergency response procedures. Extreme caution should be exercised by those working around the dam during emergency conditions when there is uncontrolled flow of water.

To facilitate the procedures, repairs of impending uncontrolled breach failures are categorized by the three most common conditions a dam owner is likely to encounter: (1) embankment overtopping, (2) embankment or foundation piping, and (3) structural failure.

<u>Embankment Overtopping</u>

If overtopping has begun or appears imminent, the following actions may be taken:

1. Notify local authorities and other affected parties of possible failure, as applicable. Implement either a full or abbreviated notification process, depending on the situation at hand.
2. Contact a qualified dam safety professional for assistance.
3. Contact a contractor or other parties that can perform the repairs, and secure necessary repair materials.
4. Notify the Indiana Department of Natural Resources, Division of Water, Dams and Levees Section within 24 hours of the incident.
5. Be sure that the spillway(s) is not plugged with debris and is functioning as efficiently as possible. Debris removal may be difficult due to pressure from the high velocity flow and should be accomplished by using long poles or hooks. Personnel should not be allowed close to spillway inlets.
6. Open all lake drains or other gates to lower the pool level. Pumps and/or siphons may also be helpful on small reservoirs.
7. Dig a by-pass channel around the dam through an abutment. The location for this channel should be chosen with extreme caution so that the embankment will not be affected by rapid erosion of the channel. This action should not be undertaken without the supervision of a qualified dam safety professional.

Figure 2-7 Uncontrolled breach of a dam caused by component failure (piping).

8. If a bypass channel is not feasible (or in addition to a bypass channel), provide erosion resistant protection on the downstream slope where overtopping is or will occur (e.g., riprap, concrete lining, plastic sheets).
9. Create additional spillway capacity by making a controlled breach in the lowest portion of the embankment, or along the abutment. Erosion resistant materials

may need to be installed on the floor and walls of the controlled breach area.

Generally, it is not recommended to temporarily raise the top of embankments with sandbags or by other means to try to prevent overtopping during a severe storm. This action is dangerous because the flood inflow may still Increase and result in the overtopping of the raised dam. If the temporarily raised dam fails, the release of an even greater volume and depth of water would result.

Obstructions in spillways are a common cause of dam overtopping.

Embankment or Foundation Piping

If piping has developed or is imminent, the following actions may be taken:

1. Determine whether the piping can lead to an uncontrolled breach failure.
2. Contact a qualified dam safety professional for assistance.
3. Notify local authorities and other affected parties of possible failure, as applicable. Implement either a full or abbreviated notification process, depending on the situation at hand.
4. Contact a contractor or other parties that can perform the repairs, and secure necessary repair materials.
5. Notify the Indiana Department of Natural Resources, Division of Water, Dams and Levees Section within 24 hours of the incident.
6. Open all lake drains and other gates to lower the pool level. Pumps and/or siphons may also be helpful on small reservoirs.
7. Attempt to plug the "pipe" at the upstream end by dumping material into the whirlpool or sinkhole. Straw has been used effectively for this purpose. If straw is not readily available, other materials (e.g., earth, rock, Bentonite, plastic, etc.) should be tried. If the "pipe" is plugged, the owner should be aware that this is only a temporary repair. The reservoir should be fully drained, and a professional engineer should be contacted to recommend permanent remedial measures.
8. Place a protective sand and gravel filter over the exit area to hold the soil material in place and ring the filter with sandbags.

Structural Failure of Embankment or Appurtenances

If a sudden and rapid failure of an appurtenance or a large slide in the embankment has occurred or is imminent, the following actions may be taken:

1. Determine whether the slide can lead to an uncontrolled breach failure.
2. Contact a qualified dam safety professional for assistance.
3. Notify local authorities and other affected parties of possible failure, as applicable. Implement either a full or abbreviated notification process, depending on the situation at hand.
4. Contact a contractor or other parties that can perform the repairs, and secure

necessary repair materials.

5. Notify the Indiana Department of Natural Resources, Division of Water, Dams and Levees Section within 24 hours of the incident.
6. Open all lake drains and other gates to lower the pool level. Pumps and/or siphons may be helpful on small reservoirs.
7. Attempt emergency repairs to prevent or delay failure.
8. Attempt to block water movement through the dam (if occurring) by placing plastic sheets, soil, etc. on the upstream face.

Slides may be caused by seepage pressures, a saturated slope, a slope which is too steep, or possibly an earthquake. Earthquakes, although not common in Indiana, can cause structural damage to the embankment or appurtenances which might lead to complete failure of the dam. If a large slide in the upstream or downstream slope has occurred which significantly lowers the dam crest and threatens to release impounded water, sandbags can be used to temporarily raise the crest to prevent overtopping. (Temporarily raising the embankment during a severe storm is not recommended.) On large reservoirs, beaching and rapid erosion of the upstream slope by wave action could occur due to high winds. A complete breach of the dam crest may result if the slope protection fails and bare soil is exposed to wave action. A supply of large rock should be available for use during this type of emergency. Severe foundation erosion and subsequent collapse of a concrete spillway may also lower the dam crest, resulting in a potential breaching condition.

Figure 2-8 Spillway component failure that could lead to uncontrolled breach failure. Note that water is flowing from under spillway.

<u>Medium priority emergency repairs</u> (emergencies that could result, or have resulted, in component failure (Type 1).

Component failure, by definition, does not result in a significant release of water. Therefore, there is usually enough time to repair the damaged components, and in some cases, temporary repairs may be made until permanent repairs can be implemented. If the component failure is rapidly progressing, it could lead to an uncontrolled breach, and immediate repairs may be required. Temporary repair of appurtenant structures will depend on the nature of the problem. The following descriptions of possible actions to take during emergencies that have or could result in component failure are offered as guidance. These measures are preliminary and may need further development in the site specific emergency response procedures.

Loss of Freeboard or Dam Cross Section due to Wave Erosion

1. Lower water level to an elevation below the damaged area.
2. Immediately place additional riprap or sandbags in damaged areas to prevent further embankment erosion.
3. Restore freeboard with sandbags or earth fill. Place suitable-sized riprap on the damaged area to stop erosion.
4. Continue close inspection of the damaged area. Mark the damage areas with stakes and monitor on a regular, frequent basis.

Slides in the Upstream or Downstream Slope of the Embankment

1. Lower water level at a rate and to an elevation which are judged to be safe under the slide condition. If the outlet is damaged or blocked then pumping, siphoning, or a controlled breach may be required.
2. Restore lost freeboard if required. This may include placing sandbags or fill on top of the slide.
3. Stabilize slides on the downstream slope by weighing the toe area with additional soil material, rock, or gravel. If there is significant leakage, construct a sand and gravel filter over the leakage exit.
4. Monitor for additional settlement, sliding, movement, and seepage.

Flows through the Embankment, Foundation, or Abutments which Erode the Materials

1. If the entrance area of the leak in the reservoir can be found, try to plug it off with whatever materials are available such as hay bales, soil, bentonite, plastic, etc.
2. Lower the water level until the flows decrease to a non-erosive velocity or until the flow stops.
3. Place a protective sand and gravel tilter over the exit area to hold the soil materials in place.
4. Continue lowering the water level until an elevation judged to be safe is reached.
5. Continue operating at a reduced level until permanent repairs can be made.
6. Monitor and document the leakage, including leakage rate and turbidity.

Embankment Cracking

1. Lower the water level by opening the outlet (and/or pumping). Continue until the water is below the cracking.
2. Attempt to block water movement into cracks by placing plastic sheeting or soil over them.
3. Mark the extent of cracking with adequate stakes in order to monitor any increase or change in pattern. Document the observations.
4. Continue operation at a reduced level until permanent repairs can be made.

Saturation of the Embankment/Abutments

1. Lower the reservoir with the outlet works to a level determined by a qualified dam safety professional or judged to be safe.
2. Monitor the conditions frequently for leakage, piping, cracking, and slides. Document the observations.
3. Continue operation at a reduced level until permanent repairs can be made.

Settlement of Embankment

1. Determine whether the settlement is related to piping. If it is, see Embankment Piping discussed earlier.
2. Survey the existing monuments to determine the amount and rate of settlement. Install measurement points if necessary. Document the observations.
3. If the settlement is greater than one-foot, lower the reservoir with the outlet works to a level determined by a qualified dam safety professional.
4. If the settlement is not related to piping, place additional fill to restore the lost freeboard.
5. Continue operating at a reduced level until repairs can be made.

Failure of Appurtenant Structures such as the Outlet or Spillway

1. Implement temporary measures to protect the damaged structure, such as closing the outlet and providing temporary protection for the damaged spillway area. Provide temporary protection at the eroding surface by placing sandbags or riprap material.
2. Experienced professional divers may be able to quickly assess the problem and possibly implement repair.
3. Lower the water level to an elevation judged to be safe. If the outlet is inoperable, then pumping, siphoning, or a controlled breach may be required.
4. Monitor the outlet and embankment for settlement, sinkholes, and muddy leakage. Monitor leakage rate.
5. Continue operating at a low water level to prevent spillway flows.

Mass Movement of the Dam on its Foundation

1. Immediately lower water level until excessive movement stops.
2. Continue lowering water until a level judged to be safe is reached.
3. Continue operating at a reduced level until repairs can be made.

Loss of Abutment Support or Extensive Cracking in Concrete Dams

1. Lower the water level by releases through the outlet.
2. Attempt to block water movement through the dam by placing plastic sheets etc., on the upstream face.
3. Prepare to notify and evacuate downstream residents.

4. Continue lowering water to a level judged to be safe.

The following suggestions may be helpful when making a controlled breach, placing sandbags, and placing plastic sheet to control leakage.

Controlled Breach

One method of making a controlled breach is to construct a small coffer dam upstream from the breach area. Then excavate the breach through the embankment and place an appropriately sized pipe through the embankment and backfill around the pipe and re-establish the dam to embankment freeboard. The coffer dam can then be removed and water released through the newly installed pipe.

A second method also starts with the construction of a small coffer dam upstream from the breach area. The breach is then excavated one to four feet below the water level. The excavation area is lined with erosion resistant material, and the coffer dam is slowly removed. The excavated breach may be made shallower and relatively wide to help minimize exit velocities.

A third method is to line the area downstream where the breach will be made, then excavate a shallow (one foot maximum) and relatively wide breach. After the water level is lowered to the invert of the breach excavation, an additional one foot of soil is excavated. This process is repeated until the reservoir level is reduced to a safe level.

Placing Sandbags

When placing sandbags in high velocity flow water, it is difficult to keep the bags in place. In order to control water in this situation it is advisable to:

1. Make sure the bags are securely tied so the material does not wash out of them.
2. Begin placement near the shore or in a quiet area and work toward the higher velocity flow areas.

Placing Plastic Sheets

Plastic sheets normally used in construction have been employed successfully to resist erosion of a dam's downstream slope or spillway channel during storm flows. The top end of the sheet must be securely anchored in a nearly horizontal area such as the crest area, where velocities are low. Closely spaced sandbags or rocks can be used to anchor the sheet and minimize flow under the sheet. This protection should be extended beyond the dam's toe or the eroding area in the spillway by overlapping with the upper sheet over the lower one and anchoring successive sheets.